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Neutrino Radar

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Abstract

We point out that with improving our present knowledge of experimental neutrino physics it will be possible to locate nuclear powered vehicles like submarines, aircraft carriers and UFOs and detect nuclear testing. Since neutrinos cannot be shielded, it will not be possible to escape these detection. In these detectors it will also be possible to perform neutrino oscillation experiments during any nuclear testing.

The difficulty of detecting neutrinos did not allow us to understand the properties of neutrinos for a long time. Only recently the atmospheric neutrino data has established neutrino oscillations in the atmospheric neutrino [1]. Recent results from SNO [2], alongwith the other solar neutrino experiments [3], have then established neutrino oscillations in solar neutrinos. The neutrinoless double beta decay has also been observed [4]. All these results have narrowed down the possible neutrino mass matrices for a 3-generation scenario [5].

The mass squared differences between different generations of neutrinos are very small and it is now realised that detecting reactor neutrinos at a distance in long baseline experiments can probe these small mass squared differences. This interest have now enriched the detector technology to detect neutrinos from reactors at a large distance. The CHOOZ [6] and palo Verde [7] reactor neutrinos have been detected at a distance of ~ 1 km. In the long-baseline experiments and Kamland neutrinos will be detected at a distance of about 200-300 kms. Detecting neutrinos from reactors at a distance of about 200 kms, Kamland will soon tell us if LMA is teh solution for solar neutrino problem.

In this article we point out that with some more improvement of our present knowledge of the neutrino detectors, it will be possible to think of some practical applications of neutrino detectors as neutrino radar. All the technology being developed could be used to develop neutrino radars, which will have future defense applications. So, developing new neutrino detectors will not only serve the purpose of precision measurements with neutrinos, but they will help us construct better defense radars.

The main idea behind the neutrino radars is that all nuclear reactors emit neutrinos in all directions and they cannot be shielded. With proper detectors these neutrinos could be detected at a distance. Another observation is that the water Cherenkov detectors can also tell us the direction of the neutrinos. With improved techniques of detectors and numerical analysis like pulse shape discrimination or the wavelet techniques, it will then be possible to reconstruct signals in the detectors, which will be able to give us real time position of the reactor source upto a certain distance, which depends on the strength of the source. The source could be nuclear submarines or any nuclear powered war vessels or some nuclear powered UFOs, which are not detectable otherwise. Since the range of these detectors could be as high as few hundred to thousand kilometers depending on their size, they can definitely detect a UFO going through our atmosphere.

Another application of these detectors would be that if there is any nuclear testing at a large distance, these detectors could give the exact location of the testing site as well as the strength of the explosion. If there are few detectors, then it may be possible to do precision neutrino experiments with them during a nuclear testing. If the testing is along the line connecting two detectors, then the first detector can give the amount of neutrino flux for calibration, while the second detector can tell us what fraction of these neutrinos have travelled the distance between the two detectors. Since the neutrino flux during a nuclear explosion will be orders of magnitude higher, these experiments could give us statistics, which may take several years by reactor experiments.

For an order of magnitude, let us first consider the range of present detectors for detecting a nuclear vessel. Different detectors are planned with different aims and none of them are aimed towards any defense applications. So, although these detectors cannot be used as neutrino radars, they can help us decide which will be the best choice for the new class of detectors. Recently the effect of nuclear submarines on the existing detectors have been studied [8], which will be taken here as the reference point for this study.

Nuclear reactors are used in submarines or aircraft carriers or other large military vessels. Thermal power of these vessels range between $0.3 - 1.0$

GW_{th}. Exact details for these vessels are not available, but this approximate range is enough for the present estimate. With a 1 kton detector mass at Kamland, a nuclear submarine at a distance of about 40 km can produce a flux of about 10^5 $cm^{-1}s^{-1}$ neutrinos giving about 100 counts per year, or a aircraft carrier at a distance of 200 km could give a flux of 10^4 $cm^{-1}s^{-1}$ neutrinos and about 10 counts per year. In Borexino, the detector mass is about 0.3 kton and the detection rate will be almost one order of magnitude less than Kamland.

With this count rate it will not be possible to locate any nuclear vessel with any real time analysis. So, the present detectors may not be used for the purpose. However, if a few detectors are placed along the coastline, and they are calibrated suitably, then it may be possible to locate any nuclear vessels. Since these detections will have directional properties, two of the detectors could give us exact location of any vessel. If there is a third detector, that can confirm this location and make the analysis easier. Coincidence between the three signals can be used to discriminate any background and increase the efficiency. Since these detectors are supposed to look for signals mostly from the sea direction, their shape could also be different from the conventional neutrino detectors.

The range of these detectors could be maximised if these detectors could be placed under water at a distance from the coast. If the detector range is about 500 km, then placing the detector at a distance of 500 km from the coast would cover a range of about 1000 km. This warrants developments of underwater neutrino detectors.

Since the range of these detectors are expected to be few hundred kms, any nuclear powered aircraft will be within the range of these detectors when they enter our atmosphere in the vicinity of the detectors. So, if any UFOs fly over the earth at a height beyond the reach of any ordinary radars, they may escape detection by the radars, but may get detected by the neutrino radars.

Taking a crude estimate of the power generated in a nuclear testing to be $4 - 6$ orders of magnitude higher than the power generated in a nuclear reactor, if any nuclear testing takes place at a distance of about 200 km from the detector, then there will be an increase in the neutrino count by the same orders of magnitude. Thus a testing taking place at a distance of about 20,000 km can also be detected by these detectors.

If a nuclear testing takes place at a distance of say, 1000 km, then the neutrino flux at these detectors will be at least two orders of magnitude higher than the flux expected from any reactors at a distance of a few km. So, if there are three detectors placed along the line of the testing site, then it may be possible to calibrate the flux by one of the detectors and then perform neutrino oscillation experiments with the data available from the next two detectors. The statistics will be much higher than any reactor neutrino experiments, which is important for any precision measurements.

As a concrete example, we consider $\bar{\nu}_e$ flux from localized sources such as reactors powering the nuclear vehicles or the same originating from nuclear blasts, as a potential candidate for detection. The reaction $\bar{\nu}_e + P \ \rightarrow \ e^+ + N$ can, not only be utilized in large liquid scintillation detectors, but also gives a positron coincidence tag at ~ 0.2 ms delay, which can be used for suppressing the background. Other major background inteferences, originating from known reactors, muon decays in the atmosphere, supernovae relics and geo-$\bar{\nu}_e$'s from the decay of $^{238}\mathbf{U}$ and $^{232}\mathbf{Th}$ [11] can, in principle, be discriminated, firstly because of the assumed transient nature of the fluxes being looked for and also due to the spectral separation of the neutrinos of reactor and other origins. For example, the geo-$\bar{\nu}_e$ events have a signal window from $1.02 - 3.26$ MeV, whereas the reactor neutrinos extend much beyond that. In fact, the precisely calculable spectral shape and flux from known reactors can be used for calibration purposes, against which the transients can be identified. It should also be mentioned that, non-$\bar{\nu}_e$ background can also originate from cosmic ray and other events mimicking the tag, which should be separated, either through concident measurements or via pulse shape analysis.

The major cause of reduction of fluxes from unknown compact sources is neutrino oscillation, through which $\bar{\nu}_e$'s can be converted to $\bar{\nu}_{\mu,\tau}$. Better detectors and more accurate measurements of $\Delta m^2 = {m_1}^2 - {m_2}^2$ and $\sin^2 2\theta$ in future, where $m_{1,2}$ are the eigenstate masses, can convert this potential weakness into a strength, by observing the survival spectrum $F^C(E_\nu)$ at different distances, as a function of energy E_ν. The source distance r and location can be estimated from $F^C(E_\nu) = \int dr F(E_\nu, r)[1 - \sin^2 2\theta \sin^2[(r/4)\Delta m^2/E_\nu]$, by observation through multiple detectors. One can also think of detection of the neutrinos belonging to the first two flavors via elastic scattering, which does not distinguish between them.

The transient nature of the fluxes from moving sources, as also the different spectral shapes of various signals, suggests the use of wavelets [12] for the purpose of data analysis. The wavelet decomposition of the signals, in terms of scale and translation variables, may turn out handy, for separating different signals in the spectral domain. Wavelets are ideal for handling irregular data series [13]. Given the observed signal, as a function of time, $y(t) = f(t) + e(t)$, where $f(t)$ is the signal and $e(t)$ is the noise, Donoho and co-workers have shown [14] the usefulness of the wavelets, in extracting $f(t)$, when the noise is below certain threshold and the signal variation is well above it. This is achieved through appropriate threshholding in the domain of wavelet coefficients. Since, the presence of transient signals produces significant signal variations, wavelets may find profitable application in the analysis of neutrino signals. It should be emphasized that, traditional methods like local smoothing, for extracting the signal will not work for the cases where, the signal is quite irregular.

In summary, we point out that improvement of the present technology of neutrino detectors may allow us to use these detectors for defense purposes. The new neutrino radars will then be capable of detecting *Nuclear powered submarines*; *Nuclear powered aircraft carriers or any other army vessels*; *Nuclear powered UFOs*; *Nuclear testing (with the information of the strength of the explosion)*; They may also be used to do neutrino oscillation experiments during any nuclear testing. Although these applications are not possible with the available and planned detectors, but all the available knowledge on neutrino detectors will be needed to design these new class of detectors. In this article we do not present any details about the type of these detectors, rather we emphasize that our present knowledge of neutrino detectors should be enriched by constructing more detectors, considering the possibility of all these defense applications. So, even if the solar neutrino problem is settled soon, we cannot afford to stop experimental neutrino physics in the near future.

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